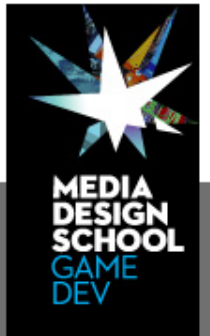
Bachelor of Software Engineering - Game Programming

GD2P02 – Physics Programming

Motion and Kinematics



Overview

- Motion and Kinematics
  - Elements of motion
  - Kinematics
  - Motion in Graphs
  - Kinematic Equations
  - Free Fall
  - Translational Motion
  - Projectile motion sample

Elements of motion

- Speed vs Velocity
  - Speed is scalar, Velocity is a vector.

- Distance vs Displacement
  - Distance is a scalar.
    - “How much ground an object has covered” during its motion.
  - Displacement is a vector.
    - It is the object’s overall change in position.

Kinematics

- The motion of points, bodies and systems of bodies.
  - **Without** consideration of the **causes** of motion!
- Kinematics is a branch of mechanics:
  - “Geometry of motion”
  - Describe the motion of objects…
    - Using: Words, diagrams, numbers, graphs and equations
  - Explain the motion of real world objects.

Velocity

- A vector that describes the direction and magnitude of the rate of change of the position of an object.
  - How the position changes with respect to time…
- Velocity = (ΔPosition) / (ΔTime)
- Remember: Δ means “change”
  - Difference Operator
  - Finite Difference

Speed

- Speed
  - Speed is the **magnitude** to the velocity vector.
    - It's a scalar quantity!
    - "How fast an object is moving"
  - speed = |Velocity|
  - speed = d / t
    - d is distance
    - t is time

Average speed and velocity

- Calculating Average Speed
  - AverageSpeed = DistanceTraveled / TimeOfTravel
- Calculating Average Velocity
  - AverageVelocity = ΔPosition / time
  - AverageVelocity = displacement / time
- Instantaneous Speed
  - The speed at any given instant in time.

Acceleration

- Acceleration is a vector defined by the rate of change of the velocity vector.
  - Has magnitude and direction…

- Acceleration = (ΔVelocity) / (ΔTime)
- Acceleration = $(V_f - V_i) / (\Delta Time)$

- SI Unit: Meters per second per second
    - (m/s^2) or (ms^{-2})
  - An object is accelerating if its velocity is changing…

Jerk

- Jerk
  - Jerk is a vector defined by the rate of change of the acceleration vector.
    - Has magnitude and direction…
  - Jerk = (ΔAcceleration) / (ΔTime)
  - Also known as:
    - Jolt, Surge, or Lurch…

Motion in graphs

- Position vs Time, Velocity vs Time, Time vs Acceleration Graphs
  - What do the following graphs look like?
    1. Constant Velocity
    2. Changing Velocity (constant acceleration/ deceleration)
    3. Changing Velocity (changing acceleration/ deceleration)

Motion in graphs: Position vs Time graphs

- The Slope of the line on the position vs time graph…
  - Is the velocity of the object!

– Slope: $= dy/dx = \Delta y/\Delta x$

$= (y_2 - y_1)/(x_2 - x_1) = \text{rise/run}$

Motion in graphs: Velocity vs Time graph

- Constant velocity:
  - Acceleration is zero.
- Increasing velocity:
  - Positive acceleration: positive velocity
  - Negative acceleration: negative velocity

- Slope of the graph is the acceleration of the object.
- Area on the graph is the displacement of the object.

Motion in graphs: Acceleration vs Time graph

- Constant acceleration
- Increasing acceleration

- Area of the graph is the velocity of the object.
- Slope is not meaningful within our context.

Kinematic Equations

- Constant velocity motion:
  - $d = v * t$
- Four kinematic equations:
  - $d = v_i t + \frac{1}{2}at^2$
  - $V_f = v_i + a t$
  - $v_f^2 = v_i^2 + 2ad$
  - $d = ((v_i + v_f) / 2)t$

- Keep in mind:
  - d : displacement
  - t : time
  - a : acceleration
  - v_i : initial velocity
  - v_f : final velocity

Free Fall

- An object in free fall is an object under only the influence of gravity.
- Two motion characteristics:
  - Free-falling objects do not encounter a significant air resistance.
  - All free-falling objects on Earth accelerate downwards at a rate of $9.8ms^{-2}$
- Acceleration of Gravity!
  - Denoted as: g = 9.8
- Ticker Tape Diagrams/Oil drop diagrams
  - Ticker marks the tape at regular time intervals…

Falling with Air Resistance

- Air resistance is in the opposite direction of gravity
  - Slows the object down: deceleration
- Terminal Velocity:
  - Air resistance force becomes large enough to balance the force of gravity.
    - Net force of zero. The object stops accelerating.
  - Terminal velocity is a constant velocity.

Translational motion

- Motion in one dimension that does not deviate from a straight line.
- For projectiles: split the motion so that components of the motion can be analyzed linearly in one dimension.
  - Free fall is in one dimension.
  - The motion of a ball thrown vertically can be analyzed in two parts: one part until the highest position, the other starting from the highest position until ball hits the ground.
  - The motion of an artillery shot can be split into two dimensional motion; vertical motion and horizontal motion.

Projectile Motion Sample: Angry Birds (Rovio, 2009)

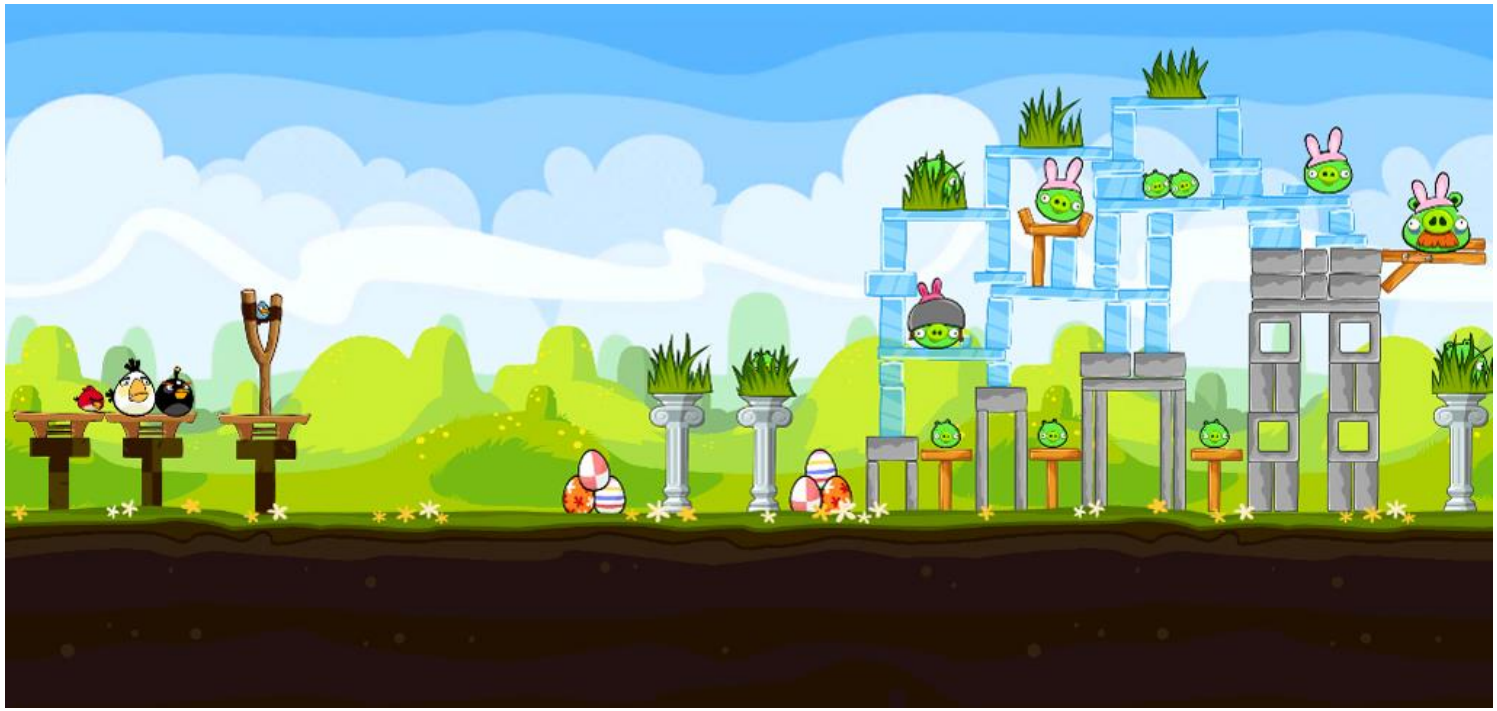


Fig 1: Angry Birds (Rovio, 2009)

Fig 1: http://www.pocketgamer.co.uk/FCKEditorFiles//angry-birds-easter-ipad-2.JPG

Angry Birds Analysis

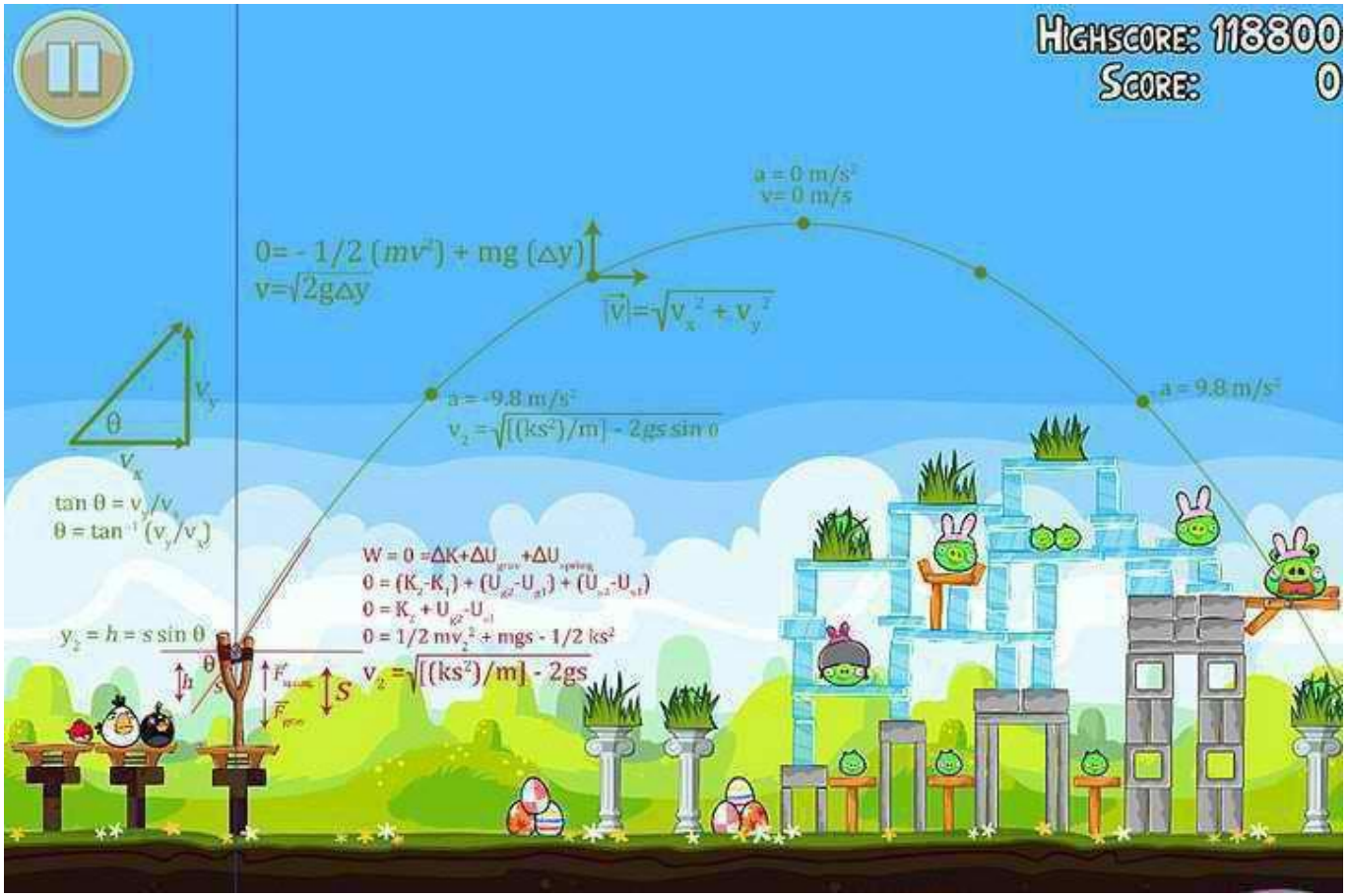


Fig 2: Angry Birds Analysis
http://communities.ptc.com/servlet/JiveServlet/showImage/102-2368-226702/376027_10150405827249928_314467614927_8272478_1598456321_n.jpg

Angry Birds Analysis: the bird

- Object leaves the catapult at a certain velocity
- Velocity has vertical and horizontal components
  - Horizontal component is constant.
    - The programmers probably ignored air resistance.
  - Vertical component subject to acceleration due to gravity.
    - Pulls the bird downward towards the Earth.
  - Kinematics rule!
- Distance is horizontal and vertical.
  - Simulate step-wise or with kinematics!
- The path travelled is parabolic.

Summary

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